Author response to referee comments on manuscript wcd-2019-19:
"The representation of Northern Hemisphere blocking in current global climate models"
by
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Francisco Doblas-Reyes, Katja Lohmann, Malcolm J. Roberts, Dmitry Sein,
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Referee comment 1, by Olivia Romppainen-Martius

This paper compares the representation of Northern Hemisphere blocking in CMIP5 and CMIP6 models for historical periods as well as high-resolution simulations with blocking in reanalysis data. The results show the CMIP6 data capture blocking better than CMIP5 and that higher resolution contributes to a better representation of blocks. However, simply increasing resolution does not completely remove biases. The results are relevant and the paper is well organized and written and the figures are clear. I therefore recommend publication after minor revisions.

We thank the referee for her interesting comments. Our point-by-point responses follow below, in blue, with the original referee comments shown in black. Modifications to the manuscript are shown in orange.

Minor points

1) Suggest to replace current with a more specific description in the title

We replace the title with the following: "Northern Hemisphere Blocking simulation in current climate models: evaluating progress from CMIP5 to CMIP6 and sensitivity to resolution".

2) L28 List the references here already

Done.

3) L69 overviewed -> listed

Done.

4) L110ff How can this blocking indicator be affected by temperature trends?

The blocking indices used in this study are calculated from the geopotential height at 500 hPa (Z500). Z500 depends on the temperature of the atmospheric layer below 500 hPa and is therefore affected by temperature trends, for example in response to anthropogenic forcing (Christidis & Stott, 2015). Thus, trends in blocking evaluated with these indices will comprise both thermodynamic and dynamic components. This issue can be dealt with by choosing indices defined in terms of a dynamical variable and by defining climatologies/thresholds separately, say, for a current and future climate period (e.g., Schwierz et al., 2004; Sillmann & Croci-Maspoli, 2009).
For the purpose of this study, namely model evaluation in a historical period, these issues are less critical, and we choose to work with Z500 because it is readily available for the different multi-model ensembles evaluated.

5) L127 Why do you include shorter lived anomalies as well?

It appears natural to us to obtain results for the empirical survival function through the entire range of persistence times. We do, however, add the subclause "…, which are not strictly considered to be blocks," in Line 129 in response to the referee's comment.

6) L146 Mention by how much they are underestimated

Done. See also comment 11 by referee 2.

7) L299ff Can you further clarify this statement, it is not obvious to me why this is the case

We have reformulated, also in response to the related comment 33 by referee 2, as follows (Line 299): "… mentioned above, and that continued model development may further reduce blocking biases."

8) A general point: please add a discussion on whether the underestimation of the longevity is the explanation for the frequency biases or if there are also differences in the number of events?

We have analysed this by decomposing the bias in blocking frequency, i.e. in the total number of blocked days, into (i) a component related to the bias in persistence, (ii) a component related to the bias in the number of blocking events, and (iii) a cross term that is small in most cases. We find that the underestimation of the number of events is the main contribution to the total bias, especially in the CMIP5 models. The improvement seen from CMIP5 to CMIP6 is primarily associated with the fact that more blocking events are simulated in the CMIP6 models. We have added a brief discussion of these results to Section 5 of the manuscript. Our results are consistent with a similar analysis carried out by Davini & D'Andrea, 2016, who find that the blocking frequency change between CMIP5/AMIP5 and multi-model ensembles from earlier MIPs is dominated by an increase in the simulated number of blocking events.

9) Figure 3ff: I do not understand why the reanalysis estimate is outside of the reanalysis variability box plot

This is because the correlation and root-mean-square error (RMSE) metrics are bounded. We estimate internal variability by forming pairs from an ensemble of simulations with a single model, and then calculate the correlations (RMSEs) between the blocking frequency patterns for each of these pairs. The expected value of these correlations (RMSEs) is less than 1 (greater then 0) due to internal variability as shown by the boxplots in the 'ERA/IV' column of the plots. The reanalysis estimates are simply shown at correlation=1 (RMSE=0) and do not take into account internal variability.

References

Christidis, N., & Stott, P. A. (2015). Changes in the geopotential height at 500 hPa under the influence of external climatic forcings. *Geophysical Research Letters*, *42*(24), 10798–10806. https://doi.org/10.1002/2015GL066669

Davini, P., & D'Andrea, F. (2016). Northern Hemisphere Atmospheric Blocking Representation in Global Climate Models: Twenty Years of Improvements? *Journal of Climate*, *29*(24), 8823–8840. https://doi.org/10.1175/JCLI-D-16-0242.1

Schwierz, C., Croci-Maspoli, M., & Davies, H. C. (2004). Perspicacious indicators of atmospheric blocking. *Geophysical Research Letters*, *31*(6), L06125. https://doi.org/10.1029/2003GL019341

Sillmann, J., & Croci-Maspoli, M. (2009). Present and future atmospheric blocking and its impact on European mean and extreme climate. *Geophysical Research Letters*, *36*(10), 1–6. https://doi.org/10.1029/2009GL038259